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On the Adaptability and Applicability of Multi-touch User Interfaces Addressing Behavioral Interventions for Children with Autism

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ABSTRACT

Principles of human-computer interaction (HCI) are imperative when it comes to efficient user interface design. This becomes even more significant when the interface is for users with special needs and especially when there is a treatment methodology incorporated in a piece of software. This study investigates user interfaces that are specifically made for children with autism-spectrum disorders. We conducted a survey to evaluate the adaptability and applicability of various interfaces. For this, we selected four of the behavioral interventions for autism namely discrete trial training (DTT), cognitive-behavioral therapy (CBT), empathy enhancement and verbal behavior approach (VBA). User interfaces (UIs) of 16 software applications were assessed for the said features. Results of this assessment revealed that these Applications were adaptable to two behavioral interventions, on the average. Moreover, these Applications were simultaneously applicable for treatment of three levels of autism; namely high functioning, low functioning, and autistic adults. These interfaces were also applicable to the children with no autism (typically developing) who acted as a controlled group.

KEYWORDS

Child computer interaction; Human-computer interaction; Multi-touch user interfaces; Multi-touch user interfaces for autism treatment

1. INTRODUCTION

Autism-spectrum disorders consist of a range of developmental impairments that cause a lack of social, communication and collaboration skills [1]. It most commonly occurs in adolescents under the age of three years. Having no timely treatment, these children can take the disorder to their adulthood, and this can cause a lot of trouble in their social lives. Unfortunately, no cure has been found for Autism until today [1]. Under these circumstances, the criticality of its treatment has risen, and multi-disciplinary interventions are being tested for providing effective cures for the disorder. These techniques can be split into two categories: medications and educational/behavioral interventions. The current domain of study is concerned with behavioral interventions that merge effective multi-touch user interfaces to better treat autism affected children [2]. Multi-touch screens are an advancement in technology and show promising results in the support of children with Autism Disorder [3]. Unlike the traditional interfaces, it allows the user to utilize the graphical interface in a natural way, and it also supports multi-user interaction. Therefore, making it extremely beneficial for enhancing the social skills of Autistic children [4].

Behavioral intervention has become standard care in the world of Autism Spectrum Disorder. As there is no "one size fits all." There are several behavioral approaches, and they can become a confusing to those unfamiliar with them: Applied Behavioral approach (ABA), Discrete Trial Training (DTT), and Cognitive-behavioral therapy behavioral therapy (CBT).

Applied Behavior Analysis, or ABA, is the most well-known behavioral intervention. In truth, ABA is something of an umbrella term, with several specific approaches falling under the general heading.

Autism spectrum further classifies into three acclaimed disorders. HF (High-Functioning), AS (Asperger Syndrome) and LF (Low Functioning). Moreover, one other category named as (TD) typically developing is also mentioned in the literature which can be simply stated as Children with no Autism.

In terms of usability, there is a need to access the adaptability of these Applications in terms of different behavioral interventions.

It needs to be explained that, which specific behavioral intervention was targeted in a software application and was it applicable for only one type of behavioral intervention or can be adapted for other interventions too. For instance, one such literature review of multi-touch applications was conducted in [5]. This review was comprehensive up to the extent that it covered

supporting hardware, considered five different projects and addressed the number of participants, duration of treatment sessions and data collection methodologies of each work. However, it gave no information about behavioral interventions addressed in each work. Neither did this review conclude about what kind of Autistics could possibly benefit from each work. According to [6,7] The currently available software applications exhibit some limitations [7]: (i) most of them are developed for high-functioning individuals; (ii) they do not have any information about behavioral interventions addressed: (iii) design of the software application is undefined; (iv) The majority of applications were developed considering changing their (Autistic kids) own emotions overlooking to teach children changing emotions of others.

The current study addresses the same issue by reviewing various multi-touch applications developed in the last decade. These Applications have been scrutinized with attention to their adaptability so that an application developed for one behavioral intervention can be used for the other interventions as well. With this problem statement in mind, we have conducted a literature review of 16 applications. Results of the comparative study showed that there are different adaptability and applicability levels in the reviewed applications, on the average. Furthermore, it is noteworthy here that behavioral therapies have a wide classification. Out of these, only those interventions have been included in the review; that is the most commonly aimed in a software application.

1.1 Significance of Adaptability in HCI

Adaptability then is concerned with the capacity to be adjusted to suiting new situations [8]. Adaptability has been acknowledged as one of the usability assessment methods. Adaptability is coined as a specific assessment factor in software quality engineering [9]. It is the ability to adjust oneself to the situation to make things suitable, to make it fit for a new use [10]. A system that allows the user to change certain system parameters and adapt their behavior accordingly is called adaptable [11]. Adaptability in learning system is a function that enables the system to fit the needs of the user in a way that they can use the specific system with great comfort, and the system shall provoke their interest for regular use. The current situation, needs, and characteristics should be taken in order to account, for example, their knowledge level, style of learning, abilities, interests, motivation and preferred language [12] So if we say that a user interface is adaptable it means that it can accomplish the following tasks: (i) Detect changes in environment (ii) Recognize the need for system change (iii) Change the system [13,14].

1.2 Significance of Applicability in HCI

Applicability means "the quality of being relevant or appropriate." There is a great deal of overlap between "adaptability" and "applicability", which makes understanding the difference more significant. Gallagher [15] has put up the term "applicability" in his book, giving an appropriate definition of it. As per Gallagher [15], HCI considers these terms as having the same meaning:

- User's Domain: Specificity
- Designer's Domain: Applicability

It means if an interface that is applicable for a behavioral intervention needs not to be adaptable at the same time for it, as to determine the adaptability of a system the application has to change and adjust according to the user, only, then we can say that it is also adaptable. In pursuit of applicability, we observe if the respective application could be utilized by children with low functioning Autism, high-functioning Autism and/or no Autism at all. Sidewise, we also see if there is applicability for Autistic Adults.

The rest of this paper is organized as follows: the next subsequent section is Section 2 that introduces readers to the four behavioral interventions addressed in the reviewed projects. Section 3 describes the review methodology that we followed to measure the adaptability and applicability in each UI. Afterward, Section 4 gives a further explanation of the measure of applicability. Finally, Section 5 summarizes the findings obtained from the above-mentioned study. After this, the conclusion section presents the deductions and proposes future recommendations.

2. BEHAVIORAL INTERVENTIONS FOR AUTISM

Autism-spectrum disorders contain a range of developmental disorders that lead to a deficit in social and communication skills in the affected children. We have categorized four of the most applied interventions due to a reason: these behavioral interventions are those that have been merged with child computer interaction-oriented applications and notable results have been obtained. In this context, there were some serious games developed in [16,17] and [13] showed reasonable improvement.

2.1 Discrete Trial Training (DTT)

In Discrete Trial Training simplified and structured steps are taught instead of teaching an entire skill in one go. After every step child's response is noticed. The goal

of this collaborative approach is to teach specific skills through systematized and a planned procedure. DTT involves a child or group of children and a trainer. There are various applications developed for DTT one such example is [18], in this application during the training sessions; the child behavior is recorded. The trainer conducts a trial and analyzes the child's response. One other application using DTT is [19] it allows children with ASD to build stories from their everyday routine stuff. The authors of [18] have also identified the gap between already developed applications using DTT approach. Most of the applications developed a focus on the subject behavior only and thus have usability, and user interface designs issues. These interfaces should be very simple as children with ASD are not comfortable with simulations, which are one of the limitations in most interfaces.

2.2 Cognitive-Behavioral Therapy (CBT)

CBT is a talking therapy, which makes the presence of the trainer a fundamental requirement in its sessions [20]. CBT based interfaces are more helpful for ASD children having anxiety disorder [21]. One such application was developed in [22] this application is explicitly developed for High-functioning ASD. It is based on the collaborative effort of CBT experts and software interface designers. It was a story table interface, and the experiment showed that the children being tested came out to be more interactive and collaborative after the experiment.

The major shortcoming in the work done on CBT is the lack of visible aids [23]. The authors of this study have suggested that integrating visible aids within behavior treatment can result better.

2.3 Empathy Enhancement (EE)

Empathy is the ability to share the internal feelings of other people [24]. While considering that the main source of that feeling is the other person [25]. That is how we as individuals understand what others are experiencing as if we were feeling it ourselves [26]. In the context of Autism treatment, the absence of empathy is a major behavioral impairment, and studies show that autistic kids are mainly suffering from reduced cognitive empathy, they have difficulty in recognizing the emotions and facial expressions of other people around them [27,28]. As far as the means of invoking empathy are concerned, this depends largely on the nature of the UI and the set of activities during the session. In this regard, it is often seen in combination with CBT or DTT. Such type of application is developed by researchers in [29] the designed UI is a game, built to treat the children with ASD by providing training. This UI mainly focuses on enhancing empathy via video stimuli (facial expression) recognition.

2.4 Verbal Behavior Approach (VBA)

It is another subclass of Applied Behavior Analysis (ABA). In comparison to DTT, it is a more interactive therapy that focuses on language skills. In contrast to the conventional ABA, the need for VBA aroused because there was not much attention given on language skills. It, therefore, makes it more flexible and is considered more helpful in ABA therapy sessions. One such attempt is made in [17]. There is a virtual agent named ANDY in the game that helps the user to socialize by tracking the eye gaze upon movement. Results showed that children made an emotional connection with the virtual agent, and few children spoke up who were non-communicative before being adapted to the game.

3. METHODS

3.1 Search Procedure/Analysis

To determine the degree of adaptability and applicability in varying applications, we first devised a set of evaluation criteria. This was imperative since the reviewed multi-touch applications were from different categories of behavioral interventions and data extraction from them required a tedious examination. Discussed below is a summary of the research methodology we followed.

We used formal methods to perform a systematic review and after careful analysis, we included only those articles that were written in English between January 2004 and April 2018.

3.2 Inclusion Procedure

We had four evaluation sessions for all the behavioral interventions mentioned if a certain study met that criterion only, then it was included into the analysis. We ultimately found 32 studies that were in accordance with our criteria. Details of the inclusion procedure are mentioned in Figure 1.

We may infer the correct results. These criteria are now listed.

a) *Check 1.* Have the authors explicitly mentioned the name of the behavioral intervention than their UI

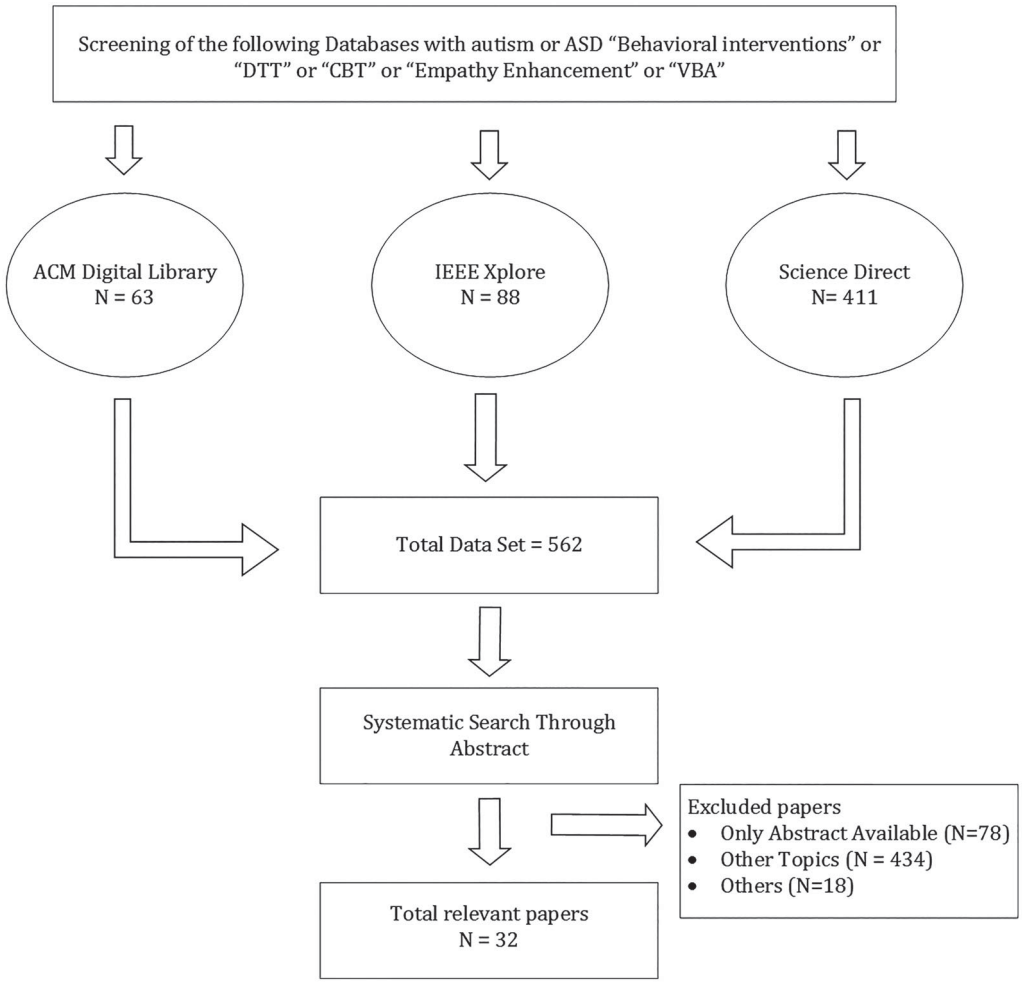

Figure 1: Flow diagram of search method used in the study

aimed for? (In most cases they did not. For instance, in the primary studies, we considered, the only one did mention the name in their title [30]; whereas one mentioned it in the abstract [31]. As far as the rest of the studies was concerned, methodical scrutiny (check 2) It was undertaken for data extraction.)

b) *Check 2.* Have the authors stated the training setup in enough detail to clarify that it included all discrete steps of DTT & that the steps are repeated after pauses (*i.e.* it includes trials)?

3.3 Evaluation Session I

3.3.1 Subordinate Research Question 1

Does the chosen applications' suite for a DTT based scenario?

a) *Check 1.* Have the authors explicitly mentioned the name of the behavioral intervention than their UI aimed for?

b) *Check 2.* Have the authors stated the training setup in enough detail to clarify that it included all discrete steps of DTT & that the steps are repeated after pauses (*i.e.* it includes trials)?

3.4 Evaluation Session II

3.4.1 Subordinate Research Question 2

Does the chosen applications' suite for a CBT based scenario?

3.4.2 Selection Criteria

To facilitate the quest for CBT potential in each UI, we worked out the following criteria:

a) *Check 1.* Does the title or abstract include the naming of CBT? If no, then use check 2.

b) *Check 2.* Does the training session involve talking therapy in any form? The forms can be.

- Conversations with the trainer (conversations that boost cognitive development)

- Talking like therapy by a virtual agent in the UI.
- Cognitive development-oriented audio feedback within the UI.

3.5 Evaluation Session III

3.5.1 Subordinate Research Question 3:

Can the chosen applications be utilized to invoke empathy in the target children?

a) *Check 1.* Does the title or abstract mention the name "empathy enhancement"?
b) *Check 2.* Have the authors mentioned increasing empathy among their goals and objectives?

3.6 Evaluation Session IV

3.6.1 Subordinate Research Question 4

Can any of the UI be employed to aid the verbal behavior approach?

a) *Check 1.* Does the study comprise special mention of VBA or interactive virtual agents in its title or abstract?
b) *Check 2.* Are there any (or multiple) virtual agents in the interface of a selected application? Are these agents responsive?

3.7 Research Question

Can he Applications build for one behavioral intervention be utilized to treat any of the other behavioral interventions?

A subjective criterion was worked out to assess the adaptability in each of the said applications. The findings of our survey showed the answer to this question, which is as follows:

Most of the Applications have a potential for adaptability in multiple behavioral interventions, as well as applicability in various autism levels.

As per this criterion, there are three levels of adaptability that a UI can have. Figure 2 shows a pictorial representation of these levels.

3.7.1 Rigid

A UI that is developed in strict compliance with a single behavioral intervention only. For instance, there is an application meant for CBT that does not follow the discrete steps of DTT; neither has it possessed any interactive virtual agents, nor it invokes empathy in any possible sense. The UI of such an application falls into the category of "rigid" adaptability.

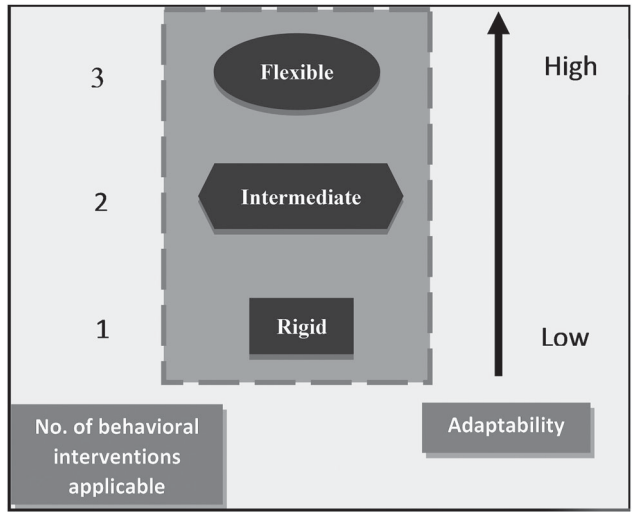

Figure 2: Subjective adaptabiltiy levels devised to analyse various UIs for adaptability in various behavioral interventions

3.7.2 Intermediate

This level was assigned to Applications that can be used for one behavioral intervention other than the primary intervention for which they were developed. This application was originally developed for CBT.

3.7.3 Flexible

A UI that is adaptable enough to fit in multiple behavioral interventions was rated as a flexible UI.

Figure 7 shows subjective adaptability levels devised to analyze various applications for different behavioral interventions.

4. MEASURE OF APPLICABILITY

A quantitative scale was devised to evaluate the applicability of each of the reviewed applications. From the literature of selected applications, we came to know that there were applications that were developed for one level of autism are applicable to another level [19,29,32,33]. According to this, we categorized the applications as Rigid, intermediate and flexible respectively. Each of the entities used in this assessment is now discussed.

4.1 Children with No Autism

This group comprises children who do not have any of the disorders in the Autism spectrum but can benefit from the Applications [34,35]. In most of the work in literature, this class has been named as "typically developing

children.". They can do this in two respects: first to cope with other developmental disorders, if they have any; and second to act as the control group in the evaluation of any UI [36].

4.2 Low-functioning Autistics

This group constitutes Autistics with an IQ level < 80. Furthermore, the distinction between low functioning & high-functioning autism also pertains to how well a child having autism can perform on daily activities and social skills. According to these criteria, low functioning autism can be subjectively termed as "severe" Autism.

4.3 High-functioning Autistics

This group of Autism affected children comprises those that have an IQ level > 80. Sometimes referred to as Asperger syndrome, HF-Autism affected children are either those that originally have less severe autism or those that have made progressive development. The latter have hence made their transition from low-functioning to high-functioning autism.

4.4 Autistic Adults

This class, though less relevant than the other three classes, cannot be neglected while covering applications for Autism. Most Applications that have been reviewed were from child computer interaction domain. Despite this, one of our objectives was to inspect the Applications in search of their applicability by Autistic adults.

5. FINDINGS

The reviewed projects were analyzed, and relevant information was obtained from each project. We have mentioned one example of each behavioral. An intervention that was addressed in the reviewed applications.

5.1 Collaborative Puzzle Game (DTT Based)

It is a serious game to teach collaborative skills in children with ASD [37]. This experiment was conducted on two groups; one group was the control group (typically developing). Another group was children with ASD. Hardware used for this software is diamond touch table. A screenshot of the user interface is reproduced in Figure 3.

5.2 The SIDES Project (CBT Based)

Shared Interfaces to Develop Effective Social Skills (SIDES) is a tool built for four player table top game [38]

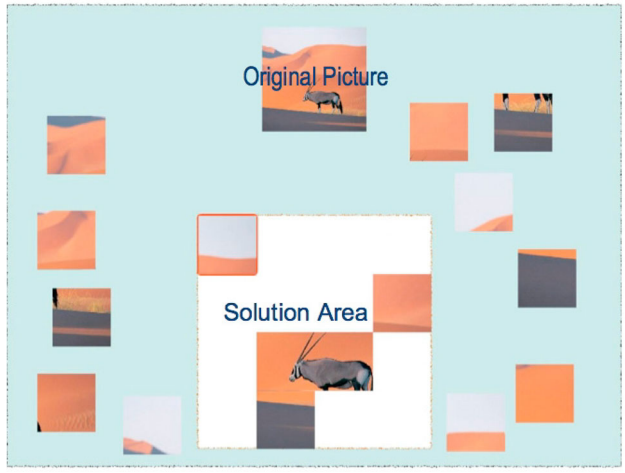

Figure 3: Screenshot of collaborative puzzle game

Figure 4: Training session on SIDES

indicator, which lights up upon the turn of that participant. To complete a level in the game all four participants have to play collaboratively. This enables children to work in a group in a controlled manner.

One training session is shown in Figure 4.

5.3 Zirkaus Empathico (EE)

Zirkaus Empathico is a serious game to improve empathy in children with ASD [31]. It has a fox as a virtual character and a circus environment having multiple levels to learn facial expressions. Upon completion of every level, the player gets a reward. The initial level consists of basic stimuli (sad, happy, fear) where the major focus is on identifying own emotions and then in later stages learning about the emotions with other people. Figure 5 shows a few pictures adapted from this game.

Figure 5: Glimpse of Zirkaus Empathico

5.4 ECHOES Serious Game (VBA Based)

The ECHOES project is a virtual character based serious game [17]. The user interface is comprised of a virtual garden having different scenarios to improve social skills. The virtual character proved helpful for children with ASD, as they started to develop a relationship with it, which ultimately helped them learning social collaborative skills. Figure 6 shows the virtual character "ANDY" and a child with ASD saying hello to him. Furthermore, the specific aspects of the behavioral intervention that fit well in the each application are mentioned in Table 1

Figure 6: Virtual character Andy and child waving hello

5.5 Adaptability of Each UI in the Benchmark Behavioral Interventions

As per our review methodology, as stated in Section 2, Our first objective was to extract data that could verify the potential of adaptability in each UI. The comparison was among the adaptability of the application software in DTT, CBT, EE and VBA therapeutic techniques. As a result of our study under four distinct evaluation sessions, we demonstrate a measure of adaptability in the Applications. This is done for each UI in the above mentioned behavioral interventions. As depicted in the statistics in Figure 8, only two of the Applications out of 16 had maximum adaptability in multiple behavioral therapy scenarios [17,39]. This is so because most of the work on different projects is done using one technique. In terms of Autism treatment, there is ample overlap between the behavioral interventions, which makes the applications adaptable to more than one intervention. Hence, most of the applications were noticed to be on an intermediate level of adaptability, which means that they could be used in one behavioral intervention other than their primary intervention. Detailed description of all the applications is mentioned in Table 2.

5.6 Assessment of Applicability of the Applications for People at Different Levels of Autism

Our second objective was to perform a review for applicability of each UI in various Autism levels. These

Table 1: Aspects of interventions used in the application

Multi-touch collaborative gesture recognition-based UI Projects	Aspects used	Applicable for Autism level**
Poetry Table using Diamond Spin tool kit	DTT Collaborative language learning was targeted	●
Zirkaus Empathico	Empathy Enhancement Recognizing Emotions and re-producing those emotions	❖
Collaborative Puzzle Game	DTT Children were trained to follow systemic steps for problem solving and making collaboration	● ⌘
SIDES	CBT Problem Solving Steps are taught to change the thinking perspective	● ⌘ ▯
I Know	DTT Discrete training sessions for quiz solving	● ❖ ⌘
I Can Tell	DTT Interaction in collaboration by using skills taught during training	● ❖
ECHOES Serious Game based Interface	VBA Virtual character was used to create a connection between kids and game	● ❖
Untangle	DTT Collaborative problem solving by understanding instructions	❖ ⌘
Photogoo	DTT Specific skills for drawing emotions on a multi-touch device, understanding language and responding to it.	❖
Music Authoring	DTT Step by step Pre-learned writing skills to make a music tone	● ❖ ⌘
Join-in Suite	CBT Audio feedback was used, and it is an essential part of CBT	⌘
No Problem	CBT A facilitator was there to help kids in training and task solving	● ❖ ⌘
Proyect@Emociones (2012)	Empathy enhancement The application includes tasks that teach the children compromise his interests with interests of others. This invokes empathy	⌘
Face 3D Ipad-based Version (2013)	VBA Virtual agents were used as a main character of the game	⌘
Racketeer (2009)	DTT Problem solving skill using game environment and following instructions	● ⌘

Note: ** ● No Autism ❖ Low functioning Autism ⌘ High functioning Autism ▯ Autism in adults.

Levels were low functioning as Autism, high-functioning Autism, and Autistic adults. Results of this analysis are shown in Figure 7. Nonetheless, Figure 7 provides a clear illustration of our findings of the adaptability and applicability in the reviewed studies.

In this respect, we assessed the literature available for each UI so that we may conclude if the final version of the software was applicable and adaptable on which type of Autistic children. In some cases, it was applicable for multiple Autism levels; while in others, the UI was strictly meant for one type. Most of the cases of the latter kind were those that were meant for HF-Autistics. This is so because low functioning Autistics are considered as having severe Autism (and are mostly of comparatively small ages). On the contrary, HF-Autistics have better communication and language skills, so they benefit more from the Applications. Still, the reviewed applications were compliant enough to be suitable for multiple levels of Autism. Figure 8 shows applicability and adaptability for each application and we can clearly see that few applications have and applicability for more than one autism level.

6. DISCUSSION

In the past two decades, a lot of work is done on children with ASD, and various applications were developed to assist children to learn social collaborative communication, and to engage them in a learning environment with the use of technology. There are two major categories of applications developed for ASD, educational and medical. In this paper, we focus only on the educational category.

Among the 32 reviewed studies based on our criteria, 68.75% ($N = 22$) were developed for high-functioning ASD [37]. 6.25%($N = 2$) required reading skills so were not accessible for a large portion of children with ASD. 9.3% ($N = 3$) required beforehand training sessions with oral instruction, which was impossible for a portion of children with ASD. 50% ($N = 16$) systems tend to emphasize training with eye contact and attention, which is also impossible for a section of children with ASD. So, only 50% ($N = 16$) applications address basic nonverbal skill. A major limitation in the applications developed so far is the lack of clinical validation based on the evidence

Table 2: Comparison of all applications in terms of objectives, functionalities and results

Project Name	Study Design, Aim	Sample Setting	Primary Behavior intervention addressed	Methods	Findings
Poetry Table with Diamond tool kit [41]	Shared table top multi-touch interface to improve social collaboration	14 children (7–11 years)	This was included to extract general information about issues in multi-touch UIs. (It is not concerned with Autism)	A room with certain arranged objects was shown and then those objects were disorganized, and children have to move the blocks of each object to their correct position. Two children have to play simultaneously. And when both were able to complete the task only then they can move to the next level.	This application was developed to improve social collaboration in typically developing children. And it does not apply to children with ASD. But for typically developing children it showed improvement in their social behavior
Zirkus Empathico [31]	To improve socio-emotional competences in pre- and primary school children	11 typically developed children 4 children with autism aged 7–12 for Pilot study. Berlin, Germany 80 children with autism aged 5–10 participated in a multicentre randomized control center RCT	Empathy enhancement based	A group of 40 students trains over 6 weeks for 100 min per week with this app	Improvement in recognizing facial expressions and a better understanding of facial emotions As the training concept was holistic the results are expected to be stable over time as measured in a three month follow up assessment
Collaborative Puzzle Game [37]	To improve collaboration in children	70 children with typical development and 16 children with ASD	Procedure was of the nature of DTT (with special focus on enforced collaboration)	Study 1(for typically developing): 70 boys divided into 2 group of 35 each with mean age 9.75 years. Before the experiment, all boys were trained individually. Total task completion time, a number of total moves, functional moves, coordination moves, the rate of simultaneous activity and relative interaction time were measured. Study 2 (kids with autism): 16 boys mean age (8–18 years)	All children showed a good level of enjoyment and all participants understood how to play. Collaboration between participants was done by verbal request or by tapping particular piece, exploiting the auditory feedback. The pairing of children was suggested by the therapist and their educators. In the training phase, the process was demonstrated. After the experiment, the level of enthusiasm varied. Lower functioning kids required additional assistance and higher functioning were immediately attracted. Visual and auditory feedback proved to be effective After statistical results it was noticed that Autistic kids used their 2/3 of time in collaborative tasks and data suggested that using enforced collaboration increases the opportunity of training that behavior that suggests social interaction.
SIDES [42]	To improve group work and social skills	4 children aged (11–14 years)	An M.Sc project from Stanford University, Education Deptt. UI was based on CBT.	It is a Four people puzzle game in which each player has 12 objects to make a path for a frog to make him reach from initial point to the final point. Group of 4 children played 6 rounds of 30 min each.	Children remained to engage in activity the entire time, but few had difficulty in navigating back. But some exhibited a higher level of control over their behavior. The conversation was improved. Coordinated very well in solving the tasks. Over all improvement in their collaborative social behavior

(*continued*)

Table 2: Continued.

Project Name	Study Design, Aim	Sample Setting	Primary Behavior intervention addressed	Methods	Findings
I Know [19]	To improve social and language skills in children	2 users(Parent/ instructor) and the child with ASD (8–12 years) 3 different scenarios of 4 min each (minimum 4 times a week)	Purely DTT based	Four people were engaged for the app design. Parent of High functioning, parent of ASD, A teacher teaching autistic children and grandparent of typically developing a child. Parents/teachers of kids with ASD could create/edit/delete quiz. The quiz is based on pics of daily life objects of children with autism	A baseline standard time was set to complete a round (typically developing kids) Children used the application with great interest and after few rounds, the result showed that they performed better than the baseline time which was remarkable.
I Can Tell [19]	To improve social and language skills in children	2 users(Parent/ instructor) and the child with ASD (8–12 years) 2 different scenarios of 3 min each (minimum 3 times a week)	Purely DTT based	Storytelling application for children. They can build a story from the pictures of their daily routine objects.	A baseline standard time was set to complete a round (typically developing kids) Children used the application with great interest and after few rounds, the result showed that they performed better than the baseline time which was remarkable
ECHOES Serious Game based Interface [17]	Virtual agent based serious game to improve social communication skills	29 children aged (8–11 years) 10–20 min playing several times a week over a period of 6 weeks	VBA based	It includes goal oriented 12 learning activities in a virtual environment to enhance the child's social communication	The children responded to the virtual agent and the virtual agent helped the children to respond to practitioner but after the statistic results due to increase in complexity of the game a growing disinterest in virtual character can be predicted. A more advanced social behavior was observed in children with ASD. Teachers compared the reaction of the kids with ASD to the virtual character with their normal class behavior and they were delighted in the improvement
Drawing [39]	To improve Social Skills (Collaboration, Coordination and Augmented Appreciation)	26 children with ASD and 40 typically developing	DTT based	It enables children to draw with stylus and zoom in/out or rotate their drawings. In this way, children can draw something they wanted to express. And this application was also used for storytelling by drawing something in groups (2–6 children).	This helped them showing how they feel about something and during the storytelling they had social interaction with having an interest that how the story will unfold step by step, by asking their peers about the next phase of the story
Untangle [39]	To Social and Language Skills	16 children with ASD and 29 typically developing	DTT based	It consists of circles (10–25) connected to each other at different points. Circles will increase as the difficulty level increases. Each set of circles should be assigned a color and then every child should untangle his/her assigned points of a circle with the help of another child such that no two points of the circle crossing each other	The result of this application was really good as children coordinated with each other to play the game and untangle their own circle, communication was both verbal and non-verbal. At several occasions, children with ASD made suggestions to the typically developing peers and it also let the children with ASD share their joy with their fellows

(*continued*)

Table 2: Continued.

Project Name	Study Design, Aim	Sample Setting	Primary Behavior intervention addressed	Methods	Findings
Photogoo [39]	To Improve Emotional Empathy	9 children with ASD 21 typically developing	DTT based	It enables the children to distort an image by dragging their fingers on the touch screen. They can modify the face of the specific cartoon to express a specific emotion	It helped children with ASD to express their emotion or understanding the emotions of their fellow peers. Results showed their level of understanding emotions was comparatively improved before and after using application
Music Authoring [39]	To improve Motor Skills	7 children with ASD and 15 typically developing	DTT based	The screen works as a harp-like a device and they can play music on low and high notes	They can create something different and it worked better when used individually. And children had fun using the application. It was also used in a collaboration. Children were divided into groups; each child can add hi/her notes and pass the tablet forward and the other child does the same helping them making a music tone in collaboration. Few children even enjoyed so much that they started dancing
Join-in Suite [38]	To improve Collaborative social competence	8 children with autism (9–12 years)	Purely CBT based	Two children will sit face to face a facilitator controls the interface from s separate panel. The application shows a social problematic situation and then both children and the facilitator reach a consensus by tapping the solution (showed by the picture)	Results showed in that in few cases one child was dominant and the other was passive one and simply followed the commands by the dominant one but as facilitator was also involved in the game, so he/she normalized the situation by helping the passive child. This resulted in the effectiveness of the interface as the facilitator has a major role to play because he/she can act as a superuser. And as a result, both the participants had to collaboratively solve the situation which resulted in more social collaboration in daily life routine issues
No Problem! [43]	To improve social interaction skills	9 children with ASD (9–13 years)	An M.Sc project from Stanford University, Education Deptt. UI was based on CBT.	Small social tasks are presented to children and they have to solve it. A facilitator uses the system to teach a pair of children about phases of the social conversation in different settings. Then children discuss the prepared solutions and they propose their own solution too.	In several tasks, the direct multi-touch interface was very effective. Results showed that such a tool can be of great help for the facilitator to teach social skills. It increased learning motivation in children with ASD. Children suggested solutions to the social tasks and communicated collaboratively to agree on a solution. Feedback was very positive from children about learning new skills and were also comfortable with using the new system

(*continued*)

Table 2: Continued.

Project Name	Study Design, Aim	Sample Setting	Primary Behavior intervention addressed	Methods	Findings
Proyect@ Emociones [36]	To improve empathy	9 children with ASD (8–11 years)	Empathy enhancement based	Multiple scenarios were given in each level of the application and for every scenario, there were different faces depicting different emotions. So according to situation children has to select the right emotional reaction to that particular situation	The system showed that children after training had a comparatively better understanding of emotions than their previous behavior and thus helping them to improve their social interaction. Few points could be more improved, buttons should be intuitive, more output options for the children. Parents also learn to interact in an enjoyable, fun and enthusiastic way with the child
Face 3D iPad-based Version [44]	Empathy enhancement and improvement in social behavior	3 children with ASD (8–10 years)	Virtual agents based on 3D graphics	The animated virtual character was used in the application. And facilitator can insert a more customized face (Parents of a child with autism) with seven standard facial expressions and can create small alterations in these expressions.	The application allowed the user to insert 3D face of people known to the kids with ASD which helped them to learn different emotions in a more customized way. Further experiments are still in progress.
Racketeer [45]	To improve Collaborative Social skills	14 children (8–12 years) Trained for 4 weeks for 1 h per week	DTT based collaborative serious game	A serious multi-touch game with 6 levels with different mathematical problems. Players have to build a rocket, collect inventor, mix fuel and to defend their rocket and ensure its launch by solving equations. At the start, each player creates their own virtual identity by choosing a virtual avatar. Player receives rewards on successful completion of each level	Apart from one child, all others reached the final level. From stats, it was concluded that children have better scores for arithmetic skills after post-game ratings. And teacher interviews show that the most anti-social child is now able to sustain cooperative play.

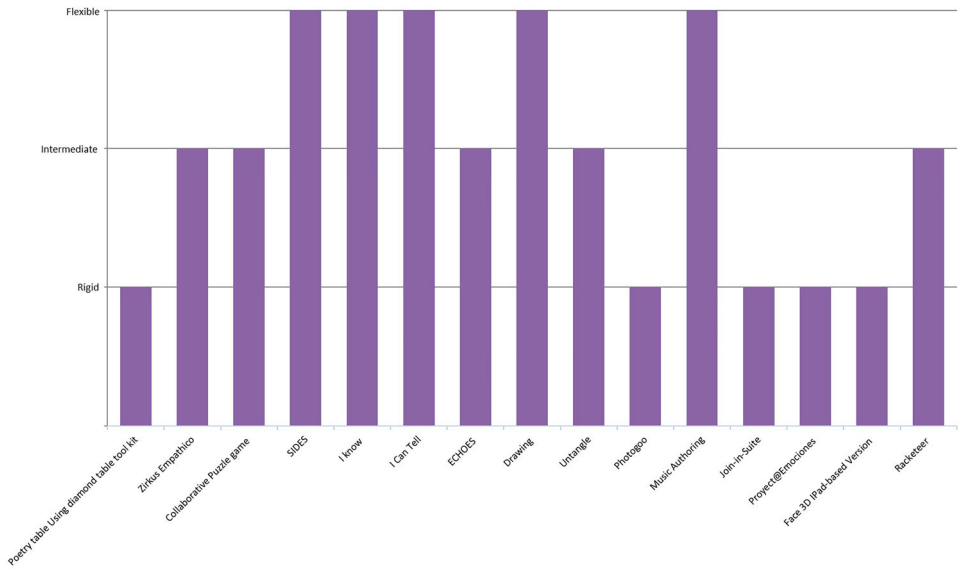

Figure 7: Finding in context of applicability and adaptability

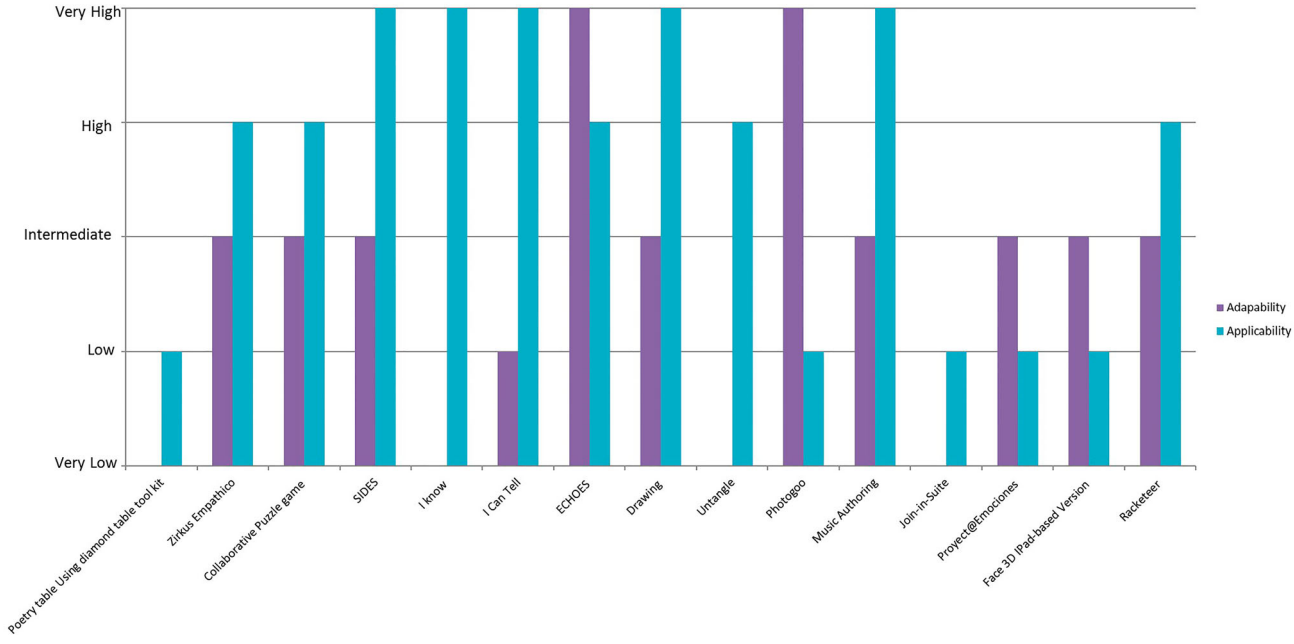

Figure 8: Applicability and adaptability of all UIs

guidelines the quality of 21.8% ($N = 7$) of the studies is poor [39]. In the majority of studies, authors have mentioned positive effects of the training provided but how long those effects lasted this is still questionable [6].

Another aspect that should be considered is the sample size. 12.5% ($N = 4$) of the cases, the sample size was not sufficient to draw concrete conclusions [40]. Another important point is the transfer of acquired skill in day to day, life for an instance learning of a specific emotion is a building block of empathy, but this does not guarantee the recognition of the same emotion in real world's social situation [43]. Secondly identifying face emotions is also not enough as it cannot be assumed that only recognizing emotion will foster social communication, there should also be more focus on producing own emotion (child with ASD), and we found 31.25% ($N = 10$) systems, which provided training on producing emotions [44]. One other problem in computer interfaces is that all the focus is on learning the skill and very less focus on motivation to use the interface repeatedly as after a few rounds the motivation level decreases. After the analysis and keeping in mind, the shortcomings in various studies we finally selected 16 applications

out of 32 and Figures 7 and 8 shows the results obtained from the evaluation of those applications. After getting the feedback on the applications necessary modifications can be done in the iteration to achieve better results.

7. CONCLUSION

The aim of this study was to investigate the already developed applications to find the potential in them to address various behavioral interventions for Autism. This way, we assessed the results available on the applicability and adaptability of various applications based on different behavioral interventions. Results of this assessment showed that applications developed for one behavioral intervention can be adapted in some other intervention session. For instance, ECHOES and Photogoo were the two applications which had maximum adaptability among all reviewed applications. This was so because they could be utilized in three different behavioral intervention setups; ECHOES, for instance, was adaptable enough to be used primarily in a DTT session, and alongside it could enhance Verbal and CBT based therapies as well. On the contrary, applications meant strictly for one type of intervention were termed as rigid and had lesser adaptability relative to ECHOES and Photogoo. As far as the applicability is concerned, 5 out of the reviewed applications turned out to be fully applicable for multiple types of Autistic subjects. Other Applications also had considerable applicability, which led us to conclude that these Applications overlapped in their use on different types of Autistic subjects. Having known this aspect and the adaptability values of Applications as a case study, parents and trainers of Autistic children can better utilize these applications with more insight of their Applications' capacity to be adaptable/ applicable in various scenarios.

8. FUTURE WORK

The currently available applications have some limitations in terms of their clinical validation. More work can be done on the integration of tracking mechanism to monitor user behavior while using the application. Majority of the Applications were developed for High Functioning (HF) autistics. With the current advancements in technology applications, considering non-verbal communication such as gesture recognition can produce best results for Low functioning (LF) autistic kids. There is very less work done on Applications allowing concurrent multiple users or a group of users whereas studies have shown that applications with more than one simultaneous user can have best results as it develops social interaction naturally [4]. Existing literature also shows that significant work is not done on sensory processing disorders, only one such UI is present, and it focuses on vision only [42]. With the latest digital technologies, it is possible to combine multisensory stimuli like vision and auditory. Moreover, the Applications should provide tools for data analysis, which can present the progress and improvement of the child's skills.

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REFERENCES

1. C. Lord, "Epidemiology: How common is autism?," *Nature*, Vol. 474, no. 7350, p. 166, 2011. doi:10.1038/474166a

2. O. Grynszpan, *et al.*, "Innovative technology-based interventions for autism spectrum disorders: A meta-analysis," *Autism*, Vol. 18, no. 4, pp. 346–61, 2014. doi:10.1177/1362361313476767

3. J. M. Smyth, "Beyond self-selection in video game play: An experimental examination of the consequences of massively multiplayer online role-playing game play," *Cyberpsychol. Behav.*, Vol. 10, no. 5, pp. 717–21, 2007. doi:10.1089/cpb.2007.9963

4. A. Hassan, M. Shafi, and M. I. Khattak, "Multi-touch collaborative gesture recognition based user interfaces as behavioral interventions for children with Autistic spectrum disorder: A review," *Mehran Univ. Res. J. Eng. Technol.*, Vol. 35, no. 4, pp. 543–60, 2016. doi:10.22581/muet1982.1604.06

5. W. Chen, "Multitouch tabletop technology for people with autism spectrum disorder: A review of the literature," *Procedia. Comput. Sci.*, Vol. 14, pp. 198–207, 2012. doi:10.1016/j.procs.2012.10.023

6. C. Grossard, *et al.*, "Serious games to teach social interactions and emotions to individuals with autism spectrum disorders (ASD)," *Comput. Educ.*, Vol. 113, pp. 195–211, 2017. doi:10.1016/j.compedu.2017.05.002

7. D. Pacella, and B. López-Pérez, "Assessing children's interpersonal emotion regulation with virtual agents: The serious game Emodiscovery," *Comput. Educ.*, Vol. 123, pp. 1–12, 2018. doi:10.1016/j.compedu.2018.04.005

8. R. Schmidt III, *et al.*, "What is the meaning of adaptability in the building industry," in *16th International Conference on Open and Sustainable Building*, 2010.

9. L. Chung, and J. C. S. do Prado Leite, "On non-functional requirements in software engineering," in *Conceptual Modeling: Foundations and Applications*, 2009, Springer, pp. 363–79.

10. D. Perez-Palacin, R. Mirandola, and J. Merseguer. "Software architecture adaptability metrics for QoS-based self-adaptation," in *Proceedings of the Joint ACM SIGSOFT Conference–QoSA and ACM SIGSOFT Symposium–ISARCS on Quality of Software Architectures–QoSA and Architecting Critical Systems–ISARCS*, 2011, ACM.

11. R. Oppermann, and R. Rasher, "Adaptability and adaptivity in learning systems," *Knowl. Transfer*, Vol. 2, pp. 173–9, 1997.

12. V. Glavinić, and A. Granić, "Hci research for e-learning: Adaptability and adaptivity to support better user interaction," in *Symposium of the Austrian HCI and Usability Engineering Group*, 2008, Springer.

13. L. Chung, and N. Subramanian, "Adaptable architecture generation for embedded systems," *J. Syst. Softw.*, Vol. 71, no. 3, pp. 271–95, 2004. doi:10.1016/S0164-1212(03)00009-8

14. N. Subramanian, and L. Chung, "Metrics for software adaptability," in *Proc. Software Quality Management (SQM 2001)*, 2001, pp. 18–20.

15. D. J. Gallagher, "Designing interaction: Psychology at the human-computer interface," *Pers. Psychol.*, Vol. 46, no. 2, p. 433, 1993.

16. K. Daouadji Amina, and B. Fatima, "MEDIUS: A serious game for Autistic children based on decision system," *Simul. Gaming.*, 2018.

17. S. Bernardini, K. Porayska-Pomsta, and T. J. Smith, "ECHOES: An intelligent serious game for fostering social communication in children with autism," *Inf. Sci.*, Vol. 264, pp. 41–60, 2014. doi:10.1016/j.ins.2013.10.027

18. V. Picardo, *et al.*, "Designing an educational tabletop software for children with Autism," in *Proceedings of the Fifteenth Australasian User Interface Conference-Volume 150*, 2014, Australian Computer Society, Inc.

19. B. Wadhwa, and C. C. Jianxiong, "Collaborative tablet applications to enhance language skills of children with autism spectrum disorder," in *Proceedings of the 11th Asia Pacific Conference on Computer Human Interaction*, 2013, ACM.

20. M. Ames, and J. A. Weiss, "Cognitive behaviour therapy for a child with autism spectrum disorder and verbal impairment: A case study," 2013.

21. J. A. Reaven, *et al.*, "Cognitive-behavioral group treatment for anxiety symptoms in children with high-functioning autism spectrum disorders: A pilot study," *Focus Autism Dev. Dis.*, Vol. 24, no. 1, pp. 27–37, 2009. doi:10.1177/1088357608327666

22. J. Mintz, "The role of user emotional attachment in driving the engagement of children with autism spectrum disorders (ASD) in using a smartphone app designed to develop social and life skill functioning," in *International Conference on Computers for Handicapped Persons*, 2014, Springer.

23. M. Kiep, A. A. Spek, and L. Hoeben, "Mindfulness-based therapy in adults with an autism spectrum disorder: Do treatment effects last?," *Mindfulness*, Vol. 6, no. 3, pp. 637–44, 2015. doi:10.1007/s12671-014-0299-x

24. I. Dziobek, *et al.*, "Dissociation of cognitive and emotional empathy in adults with Asperger syndrome using the Multifaceted Empathy Test (MET)," *J. Autism Dev. Disord.*, Vol. 38, no. 3, pp. 464–73, 2008. doi:10.1007/s10803-007-0486-x

25. J. Decety, and C. Lamm, "Human empathy through the lens of social neuroscience," *Sci. World J.*, Vol. 6, pp. 1146–63, 2006. doi:10.1100/tsw.2006.221

26. C. Schwenck, *et al.*, "Empathy in children with autism and conduct disorder: Group-specific profiles and developmental aspects," *J. Child Psychol. Psyc.*, Vol. 53, no. 6, pp. 651–9, 2012. doi:10.1111/j.1469-7610.2011.02499.x

27. D. Bons, *et al.*, "Motor, emotional, and cognitive empathy in children and adolescents with autism spectrum disorder and conduct disorder," *J. Abnorm. Child Psychol.*, Vol. 41, no. 3, pp. 425–43, 2013. doi:10.1007/s10802-012-9689-5

28. M. B. Harms, A. Martin, and G. L. Wallace, "Facial emotion recognition in autism spectrum disorders: A review of behavioral and neuroimaging studies," *Neuropsychol. Rev.*, Vol. 20, no. 3, pp. 290–322, 2010. doi:10.1007/s11065-010-9138-6

29. D. Zoerner, *et al.*, "Zirkus Empathico: Mobile training of socio-emotional competences for children with Autism," in *Advanced Learning Technologies (ICALT), 2016 IEEE 16th International Conference on*, 2016, IEEE.

30. R. Muñoz, *et al.*, "Development of software that supports the improvement of the empathy in children with autism spectrum disorder," in *Chilean Computer Science Society (SCCC), 2012 31st International Conference of the*, 2012, IEEE.

31. M. Zancanaro, *et al.*, "Three around a table: The facilitator role in a co-located interface for social competence training of children with autism spectrum disorder," in *IFIP Conference on Human-Computer Interaction*, 2011, Springer.

32. J. P. Hourcade, N. E. Bullock-Rest, and T. E. Hansen, "Multitouch tablet applications and activities to enhance the social skills of children with autism spectrum disorders," *Pers. Ubiquitous. Comput.*, Vol. 16, no. 2, pp. 157–68, 2012. doi:10.1007/s00779-011-0383-3

33. A. M. Piper, *et al.*, "SIDES: A cooperative tabletop computer game for social skills development," in *Proceedings of the 2006 20th Anniversary Conference on Computer Supported Cooperative Work*, 2006, ACM.

34. M. F. Young, *et al.*, "Our princess is in another castle: A review of trends in serious gaming for education," *Rev. Educ. Res.*, Vol. 82, no. 1, pp. 61–89, 2012. doi:10.3102/0034654312436980

35. S. Suh, S. W. Kim, and N. J. Kim, "Effectiveness of MMORPG-based instruction in elementary English education in Korea," *J. Comput. Assist. Learn.*, Vol. 26, no. 5, pp. 370–8, 2010. doi:10.1111/j.1365-2729.2010.00353.x

36. S. Holt, and N. Yuill, "Facilitating other-awareness in low-functioning children with autism and typically-developing preschoolers using dual-control technology," *J. Autism Dev. Disord.*, Vol. 44, no. 1, pp. 236–48, 2014. doi:10.1007/s10803-013-1868-x

37. A. Battocchi, *et al.*, "Collaborative puzzle game: A tabletop interactive game for fostering collaboration in children with Autism Spectrum Disorders (ASD)," in *Proceedings of the ACM International Conference on Interactive Tabletops and Surfaces*, ACM, 2009.

38. A. M. Piper, *et al.*, "SIDES: A cooperative tabletop computer game for social skills development," in *Proceedings of the 2006 20th Anniversary Conference on Computer Supported Cooperative Work*, ACM, 2006.

39. M. B. Lauritsen, "Autism spectrum disorders," *Eur. Child Adolesc. Psychiatry*, Vol. 22, no. 1, pp. 37–42, 2013. doi:10.1007/s00787-012-0359-5

40. W. Chen, "Multitouch tabletop technology for people with autism spectrum disorder: A review of the literature," *Procedia Comput. Sci.*, Vol. 14, pp. 198–207, 2012.

41. C. Shen, *et al.*, "DiamondSpin: An extensible toolkit for around-the-table interaction," in *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, ACM, 2004.

42. M. Roglić, *et al.*, "Serious gaming based on Kinect technology for autistic children in Serbia," in *Neural Networks and Applications (NEUREL), 2016 13th Symposium on*, 2016, IEEE.

43. S. Serret, *et al.*, "Facing the challenge of teaching emotions to individuals with low-and high-functioning autism using a new Serious game: A pilot study," *Molecular Autism*, Vol. 5, no. 1, pp. 37, 2014.

44. T. Fernandes, *et al.*, "LIFEisGAME: A facial character animation system to help recognize facial expressions," in *International Conference on ENTERprise Information Systems*, Springer, 2011.

45. M. Van Veen, *et al.*, "Improving collaboration skills for children with PDD-NOS through a multi-touch based serious game," in *Proceedings of International Conference of Education and New Learning Technologies*, 2009.

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